Adjunctive therapies for the nonsurgical treatment of peri-implant diseases: systemic review and meta-analysis

yuhan xiao
Sichuan University West China College of Stomatology https://orcid.org/0000-0002-7636-560X
Yichun Qin
Sichuan University West China College of Stomatology
Haiyang Yu (YHYmechanics@163.com)
https://orcid.org/0000-0003-0184-5278

Research article

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Abstract

Background Peri-implant diseases are caused by biofilms around the implant and may lead to implant failure. Non-surgical mechanical debridement with different adjunctive therapies has being applied in the treatment of peri-implant diseases. This systematic review aims to figure out whether one adjunctive therapy is superior to any other. Methods Two independent authors screened the literature via the MEDLINE and Cochrane Library. Only clinical randomized controlled trials (RCTs) that compared the efficacy of adjunctive therapies in the treatment of experimental peri-implant mucositis with non-surgical mechanical debridement (MD) were included in this review. The studies selected were published before February 2020. Comparisons of clinical outcomes were estimated using meta-analysis Results: A total of thirty-one RCTs met the inclusion criteria. The following adjunctive interventions were compared in the included studies: modifying the prosthesis; air abrasive; Er:YAG laser; diode laser; photodynamic therapy; local antibiotics; system antibiotics; probiotics; enamel matrix derivative. Follow-up ranged from 3 months to 1 years. Statistically significant difference was observed between MD with photodynamic therapy and MD alone at 3 months follow-up ($P < 0.01$). There is no statistical difference between MD with chlorhexidine and MD alone at 3 months follow-up ($P = 0.61$), so is MD with probiotics and MD alone ($P = 0.47$), and so is systemic antibiotics and MD alone ($P = 0.96$). Conclusion.At present, we do not know which non-surgical intervention is superior to any other, and for the interventions having similar degrees of effectiveness we do not know which one has less side effects, is simpler and cheaper to use. It is necessary to conduct well-designed RCTs with longer follow-ups to assess the accurate effectiveness of therapies.

Background

Peri-implant diseases include Peri-implant mucositis and peri-implantitis. Peri-implant mucositis is a reversible inflammatory response of the mucosa adjacent to the implant without bone loss. Peri-implantitis, instead, has been defined as an inflammatory process that affects the soft tissues surrounding an osseointegrated implant in function with concomitant loss of supporting marginal bone[1, 2]. Peri-implant diseases are caused by biofilms around the implant in susceptible individuals, affecting inflammation of peri-implant tissues. The incidence of peri-implant diseases is not low. According to a review, peri-implant mucositis occurs in approximately 80% of patients (50% of the implant), and in 28–66% of the patients (12–40% of the implant), the disease translates into Peri-implantitis[3].

Inflammation of peri-implant tissues is caused by peri-implant biofilms in susceptible individuals[4]. Decontamination of the implant surface and eradication of the biofilm and endotoxins are the major challenge in the treatment of peri-implant diseases[5]. Mechanical debridement (MD) is recognized as indispensable, basal procedure in the non-surgical treatment. MD can improve outcomes, such as clinical attachment level (CAL) gain and pocket probing depth (PPD) reduction[6]. However, in some clinical studies, several weeks after MD, there was a recurrence of the disease in a significant percentage of patients[7, 8]. The complete resolution after MD is still not frequent event.

To assist MD in treating peri-implant diseases, researchers have applied various adjunctive therapies to enhance clinical outcomes. These adjunctive therapies include: 1) air abrasive; 2) Er:YAG laser; 3) diode laser; 4) photodynamic therapy; 4) local drug delivery (e.g. chlorhexidine gel, chloramine or probiotic); 5) systemic antibiotics; 6) matrix chips; 7) modifying the prosthesis; 8) the combination of some of the above therapies. Many literatures compared these adjunctive therapies, and the results were diverse[9–39]. There is no consensus regarding the optimal protocol for non-surgical treatment of peri-implant diseases. A systematic comparison of different adjunctive therapies for the peri-implant diseases has not yet been undertaken. Henceforth, the present systematic review aims to figure out whether one adjunctive therapy of non-surgical decontamination is superior to any other.

This systematic review was designed and conducted in accordance with the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) 2015 statement[40].

Methods

Inclusion criteria

Only clinical randomized controlled trials (RCTs) that reported adjunctive therapies for non-surgical treatment of peri-implant diseases published before February 2020 were considered eligible for inclusion in this review. No language restrictions were applied.

Exclusion criteria

Studies requiring an additional surgical technique, such as flap surgery, guided bone regeneration or any grafting procedure were excluded. Letters to the editor, reviews, cross-sectional studies, case reports, animal studies, in vivo, and ex vivo studies were also excluded.

Screening process

Searches were performed without language restrictions in MEDLINE (PubMed) and the Cochrane Library databases until February 1, 2020. For the PubMed library, the key terms used were as follows: (((((dental implant [MeSH Terms]) OR oral implant [MeSH Terms]) AND therapy) OR treatment) AND peri-implantitis). On the other side, for the Cochrane Libraries the key terms used were: (Title, Abstract, Keywords): dental implant AND therapy OR treatment AND peri-implantitis. The screening in such databases “humans” and “clinical trials” were applied as restricted studies. The electronic search was complemented by manual searches of the reference lists of the selected publications, including Journal of Dental Research, Journal of Clinical Periodontology, Journal of Periodontology and the International Journal of Periodontics and Restorative Dentistry, from January 2019 up to February 2020

A total of two calibrated independent reviewers (YHX & YCQ) screened all titles/abstracts and the full texts of the articles were retrieved by the search strategy. The articles that fulfilled the eligibility criteria were included in the present study. The reviewers searched the reference lists of the included articles for

additional relevant publications. Any discrepancies between the two reviewers were resolved following additional discussion with a third reviewer (HYY).

Quality assessment

A quality assessment of the included studies (RCTs) was done following the recommendations for systematic reviews of interventions of the Cochrane collaboration[41], focusing on the following criteria: random sequence generation and allocation concealment (both accounting for selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment. (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias), or other possible causes of bias.

Data extraction and statistical analysis

Two independent reviewers (YHX & HLJ) extracted the data. Disagreements between the two reviewers were resolved following additional discussion with a third reviewer (HYY). A standardized data extraction form was used to collect the following data: 1) author, year; 2) number of patients; 3) number of implants; 4) mean age of the patients; 5) years of implant in function; 6) gender distribution; 7) smoker; 8) history of periodontitis; 9) length of follow-up; 10) whether following the CONSORT[42]; 11) adjunctive treatments; 10) clinical outcomes, including method of assessment and time intervals..

Meta-analysis was performed using the Review Manager software (Review Manager version 5.3; The Cochrane collaboration, Copenhagen, Denmark). The statistical heterogeneity among the RCTs selected for meta-analysis was assessed utilizing the DerSimonian–Laird estimate τ^2 for inter study variance. Because each clinical outcome was evaluated in a similar way, preferring smaller values, so meta-analysis could be performed together. The meta-analysis was performed to investigate on a standardized mean difference between the clinical outcomes in the groups of adjunctive therapies compared with MD. For continuous outcomes, mean differences and standard deviations were used to summarize the data for each group using mean differences and 95% CIs.

Results

The initial search yielded 1621 publications found in PubMed Library and 1460 in Cochrane Library. Four more publications were identified by manual search. After removing duplicate studies, there were 1684 publications of potential interest to screen. After excluding articles based on their titles and abstracts, 35 studies were left for full-text assessment. Following a discussion after full-text analysis, 31 studies were included for systematic review and qualitative synthesis. The process of identification of the included studies from the initial yield is described in Fig. 1. The numbers of patients, mean age, gender distribution, implant data and adjunctive treatments are listed in Table 1.

Table 1
Description of included studies.

Author, year	Patients (n)	Gender (M/F)	Age (mean/SD, years)		Implants (n)		Years of implant in function (mean/SD)		Current smokers		Follow-up (months)	Follow the CONSORT	Adjunctive treatments
			T	C	T	C	T	C	T	C			
Tapia et al. 2019	45	23/22	60.9/9.9	61.2/12.9	73	72	10.2/5.4	9.1/4.8	1	1	6 m	Y	T: Modifying the prosthesis C: None
Ji et al. 2012	24	10/14	46.2	41.3	17	16	-	-	0	0	3 m	NR	T: Air abrasive C: None
Persson et al. 2011	42	12/29	68.5/6.4	68.9/12.5	55	45	-	-	-	-	6 m	Y	T: Er:YAG laser C: Air abrasive
Schwarz et al. 2003	20	12/8	48	51	16	16	4.1	4.3	-	-	6 m	NR	T: Er:YAG laser C: 0.2% Chlorhexidine digluconate
Arısan et al. 2015	10	3/7	-	-	24	24	-	-	-	-	6 m	Y	T: Diode laser C: None
Aimetti et al. 2018	220	71/149	58.1/10.1	56.8/10.2	110	110	6.8/3.6	7.4/4.4	14	20	4 m	NR	T: Diode laser C: None
Birang et al. 2017	20	10/10	-	-	20	20	-	-	-	-	3 m	NR	T: Diode laser C: Photodynamic therapy
Rifaiy et al. 2017	38	38/0	33.6/2.8	35.4/2.1	38	27	4.06	4.36	20	18	3 m	Y	T: Photodynamic therapy C: None
Karimi et al. 2016	10	2/8	-	-	15	15	-	-	-	-	3 m	NR	T: Photodynamic therapy C: None
Javed et al. 2016	166	120/46	41.1	39.4	127	122	4.1	4.9	41	43	12 m	NR	T: Photodynamic therapy C: None
Javed et al. 2017	54	54/0	50.6/0.8	52.2 ± 0.5	28	26	-	-	28	26	3 m	NR	T: Photodynamic therapy C: None
Wang et al. 2019	131	48/53	44.1/9.8	42.6 ± 13.0	66	65	-	-	13	21	6 m	Y	T: Photodynamic therapy C: None
Bassetti et al. 2014	40	20/20	59	57	20	20	7.3	7.2	-	-	12 m	NR	T: Air abrasive & Photodynamic therapy C: Air abrasive & 1 mg Minocycline
Schar et al. 2012	40	20/20	59	57	20	20	7.3	7.2	-	-	6 m	NR	T: Air abrasive & Photodynamic therapy C: Air abrasive & 1 mg Minocycline
Heitz et al. 2011	29	-	57	53	14	15	-	-	2	2	3 m	NR	T: 0.5% Chlorhexidine gel C: None

M: male; F: female; T: test group; C: control group; Y: yes; NR: not report.

Author, year	Patients (n)	Gender (M/F)	Age (mean/SD, years)		Implants (n)		Years of implant in function (mean/SD)		Current smokers		Follow-up (months)	Follow the CONSORT	Adjunctive treatments
			T	C	T	C	T	C	T	C			
Menezes et al. 2016	37	6/31	57.4/9.1	57.4/13.0	61	58	-	-	-	-	6 m	NR	T: 0.12% Chlorhexidine Gluconate C: None
Pulcini et al. 2019	46	21/25	61.3/8.9	61.0/12.0	22	24	-	-	2	4	12 m	Y	T: Air abrasive & 0.03% Chlorhexidine rinse C: Air abrasive & 0.05% Chlorhexidine rinse
Porras et al. 2002	16	-	-	-	16	12	-	-	-	-	3 m	NR	T: 0.12% Chlorhexidine rinsing & 0.12% Chlorhexidine gel C: None
Pena et al. 2019	50	21/29	56.0/10.8	61.2/10.6	25	25	-	-	0	1	4.5 m	Y	T: 0.12% Chlorhexidine rinse & Lactobacillus reuteri probiotic C: 0.12% Chlorhexidine rinse
Renvert et al. 2008	32	10/22	60.8/12.7	62.4/7.7	57	38	-	-	2	5	12 m	NR	T: 1 mg Minocycline C: 1% Chlorhexidine gel
Renvert et al. 2006	30	12/18	65.6/8.6	61.1/8.6	16	14	-	-	5	3	12 m	NR	T: 1 mg Minocycline C: 1% Chlorhexidine gel
Sahrmann et al. 2019	32	16/16	60.0	57.5	17	15	5.6/1.6	5.5/1.8	1	3	6 m	NR	T: Chlorhexidine chip C: Chlorhexidine gel
Roos et al. 2017	16	-	-	-	16	16	-	-	-	-	3 m	Y	T: Chloramine C: None
Levin et al. 2015	37	19/20	-	-	18	19	-	-	-	-	3 m	NR	T: Dental water jet rinse mixed with chlorhexidine gel C: None
Shibli et al. 2019	40	11/29	-	-	20	20	-	-	-	-	12 m	NR	T: Systemic antibiotics C: None
Hallstrom et al. 2012	43	-	54.6/18.2	54.6/19.8	22	21	10.9/4.6	10.0/5.2	-	-	6 m	Y	T: Systemic antibiotics C: None
Galofre et al. 2018	44	23/21	61.6/12.5	58.4/13.3	22	22	-	-	-		3 m	Y	T: Lactobacillus reuteri probiotic C: None
Laleman et al. 2020	19	9/10	64/11	69/9	9	10	-	-	0	0	6 m	Y	T: Lactobacillus reuteri probiotic C: None

M: male; F: female; T: test group; C: control group; Y: yes; NR: not report.

Author, year	Patients (n)	Gender (M/F)	Age (mean/SD, years)		Implants (n)		Years of implant in function (mean/SD)		Current smokers		Follow-up (months)	Follow the CONSORT	Adjunctive treatments
			T	C	T	C	T	C	T	C			
Tada et al. 2018	30	8/22	68.8/7.5	65.9/8.8	15	15	8.3/4.2	6.0/2.8	3	1	6 m	Y	T: Lactobacillus reuteri probiotics & system antibiotics C: None
Machtei et al. 2012	60	25/35	60.95/7.9	57.4/10.5	37	40	-	-	5	5	6 m	Y	T: Biodegradable crosslinked gelatin matrix chips C: Matrix containing 2.5 mg chlorhexidine-gluconate chips
Kashefimehr et al. 2016	41	21/20	50.0/2.9	45.6/2.9	74	63	2.0/0.2	2.2/0.2	-	-	3 m	Y	T: Air abrasive & 0.12% chlorhexidine mouthwash C: Air abrasive & 0.12% chlorhexidine mouthwash & enamel matrix derivative

M: male; F: female; T: test group; C: control group; Y: yes; NR: not report.

Quality assessment

14 of 31 RCTs were designed according to CONSORT. Results of the quality assessment of RCTs are listed in Table 2, following the recommendations[41]. The difference of the assessment results was low and the consent was reached by discussion.

Table 2

Results of the quality assessment of RCTs.

author, year	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Tapia et al. 2019	Low	High	Low	Low	Low	Low
Ji et al. 2012	Low	Low	Unclear	High	Low	Low
Persson et al. 2011	Low	Low	Unclear	Low	Low	Low
Schwarz et al. 2003	Low	Low	Low	Unclear	Low	Low
Arısan et al. 2015	Low	Unclear	Low	Low	High	Low
Aimetti et al. 2018	Low	Unclear	Unclear	Unclear	Low	Low
Birang et al. 2017	Low	Unclear	Unclear	Low	High	Low
Rifaiy et al. 2017	Low	Low	Low	Unclear	Low	Low
Karimi et al. 2016	Low	Low	Low	Unclear	Low	Low
Javed et al. 2016	Low	Low	Unclear	Unclear	High	Unclear
Javed et al. 2017	Low	Low	Unclear	Unclear	Low	Low
Wang et al. 2019	Low	Low	Low	Unclear	Low	Low
Bassetti et al. 2014	Low	Unclear	Low	Unclear	Low	Low
Schar et al. 2012	Low	Low	Low	Low	Low	Low
Heitz et al. 2011	Low	Low	Low	Low	Low	Low
Menezes et al. 2016	Low	High	Unclear	Unclear	Low	Low
Pulcini et al. 2019	Low	Low	Low	Low	Low	Low
Porras et al. 2002	High	High	High	Unclear	Low	Low
Pena et al. 2019	Low	Low	Low	Low	Low	Low
Renvert et al. 2008	Low	High	Low	Unclear	Low	Low
Renvert et al. 2006	Unclear	Unclear	Low	Low	Low	Low
Sahrmann et al. 2019	Low	Low	Low	Unclear	Low	Low
Roos et al. 2017	Low	Low	Unclear	Low	High	Low
Levin et al. 2015	Low	Low	Unclear	Low	High	Low
Shibli et al. 2019	Low	Low	Low	Unclear	High	Low
Hallstrom et al. 2012	Low	Low	Low	Unclear	Low	Low

author, year	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)
Galofre et al. 2018	Low	Unclear	Unclear	Low	Low	Low
Laleman et al. 2020	Low	Unclear	Low	Low	Low	Low
Tada et al. 2018	Low	Low	Unclear	Low	Low	Low
Machtei et al. 2012	Low	Low	Low	Unclear	Low	Low
Kashefimehr et al. 2016	Low	Low	Unclear	Low	Low	Low

Meta-analysis

Meta-analysis was carried out, including data reporting mean values of pocket probing depth (PPD), bleeding of probing (BOP), clinical attachment loss (CAL) and plaque index (PI), comparing the outcomes of MD combined with photodynamic therapy, chlorhexidine, systemic antibiotics or probiotics with MD alone. The follow-up time for each study was not the same, so only the most comprehensive results reported at 3 months were included. For meta-analysis, summary measures of each included study were used only, because individual data could not be extracted from the studies. Subgroup analyses of these studies concerning different clinical outcomes were performed.

Because of different measurement methods, standardized mean difference was investigated to compare the clinical outcomes in the groups of adjunctive therapies and MD. Standardized mean difference of clinical outcomes (BOP, CAL, PPD) of 0.60 ($CI_{95\%}$ -1.20; 2.40) between group MD with photodynamic treatment and group MD alone was found significantly different from 0 ($P < 0.01$). Standardized mean difference of clinical outcomes (BOP, PPD) of -0.01 ($CI_{95\%}$ -0.24; 0.22) between group MD with chlorhexidine treatment and group MD alone was found no significant difference from 0 ($P = 0.61$). Standardized mean difference of clinical outcomes (BOP, PPD) of -0.02 ($CI_{95\%}$ -0.32; 0.29) between group MD with systemic antibiotics treatment and group MD alone was found no significant difference from 0 ($P = 0.47$). Standardized mean difference of clinical outcomes (BOP, PI, PPD) of -0.26 ($CI_{95\%}$ -0.54; 0.03) between group MD with probiotics treatment and group MD alone was found no significant difference from 0 ($P = 0.96$). Figure 2–5 depict the forest plot of standardized mean differences of clinical outcomes between MD with adjunctive therapies and MD alone.

Discussion

Photodynamic therapy involves interactions between a light source and a photosensitizer in an aerobic environment. This results in the generation of free oxygen radicals that damage target cells such as bacterial cells[43]. Photodynamic therapy has also been reported to kill pathogenic microbes associated with the etiology of periodontal and peri-implant disease such as Aggregatibacter actinomycetemcomitans (A. actinomycetemcomitans), Prevotella intermedia, and Porphyromonas gingivalis (P. gingivalis)[44]. MD with adjunct photodynamic therapy is more effective in reducing peri-implant PPD than MD alone at 3 months following treatment (Fig. 2). However, in the long-term outcomes of MD either with or without photodynamic therapy are comparable[18].

Adjunct use of diode laser did not yield any additional positive influence on the peri-implant healing compared with MD alone at 3 months or 6 months following treatment[14, 45]. Two included RCTs were about the effect of Er:YAG laser (ERL) as an adjunct in the treatment of peri-implant diseases. Studies have indicated that nonsurgical periodontal treatment with an ERL significantly improve clinical outcomes as evidenced by PPD reduction and gain of CAL[46, 47]. The sites treated with ERL demonstrated a mean CAL change from 5.8 ± 1 mm at baseline to 5.1 ± 1.1 mm after 6 months. Frank et al.[12] found that ERL could also reduce BOP significantly at 6 months following treatment. Further studies are needed to compare the effectiveness of ERL modality to that of other adjunctive therapies.

A total of two included RCTs were about the effect of air abrasive as an adjunct in the treatment of peri-implant diseases[10, 11]. Both found that adjunctive air abrasive treatment seemed to have a limited beneficial effect as compared with MD alone. Air abrasive devices have been shown to be a feasible treatment option in periodontal care because it has the potential to effectively erase biofilms[48]. However, professional MD can effectively remove biofilms where the instruments can reach, thus the adjunctive effect of air abrasive may be limited.

Chlorhexidine is a commonly used topical drug. As shown in Fig. 3, compared with MD alone, MD with chlorhexidine have a limited beneficial effect at 3 months following treatment. An included article reported the adjunctive effect of chloramine and found that chloramine could not improve the clinical outcomes of peri-implant diseases[31]. The effects of probiotic Lactobacillus reuteri in combination with MD were evaluated in implants with peri-implantitis, and no clinical differences between probiotic and placebo treatments were observed over time[35, 36] (Fig. 4). On the contrary, minocycline microspheres as an adjunct to MD treatment of incipient peri-implantitis lesions demonstrated improvements in PPD and BI that were sustained over 6 months[28, 29]. The state of the topical drugs, the concentrations of the topical drugs and the way of delivering topical drugs may affect the effectiveness of the drugs. Dental water jet rinse mixed with chlorhexidine gel might supplement the response to nonsurgical treatment for peri-implantitis lesions by reducing PPD[32]. Studies have found that repeated chlorhexidine chips application might resolve marginal peri-implant inflammation in terms of BOP better than chlorhexidine gel, and PPD was more reduced with 0.65 ± 0.40 mm [30, 38]. The efficacy of a single dose is limited, repeated application of local drugs can prolong the effectiveness.

However, the frequent use of antibiotics causes bacterial resistance in the subgingival biofilm[49]. There is no consensus on how to deliver topical drugs in the treatment of peri-implant diseases. Therefore, further studies are warranted.

Standardized mean difference of clinical outcomes (BOP, PPD) between group MD with systemic antibiotics treatment and group MD alone was found no significant difference from 0 (P = 0.47) (Fig. 5). So far, the studies have not provided evidence for the use of systemic antibiotics in treatment of peri-implantitis[33, 34].

Tapia et al.[9] found that modifying the contour of the prostheses after mechanical debridement significantly improved the clinical outcomes of peri-implant mucositis. This conclusion was correlated to the inclusion criteria of the study, which required the included patients to have at least one implant supported restoration with an inappropriate prosthesis design or contour that made difficult oral hygiene access to the neck of the implant. Implant supported prosthesis design is important to promote accessibility to oral hygiene around implants[50], which suggests a way to treat peri-implantitis.

Enamel matrix derivatives have been employed successfully in the management of periodontal diseases and in particular bone loss associated with periodontitis[51]. Kashefimehr et al.[39] studied the effects of enamel matrix derivative on non-surgical management of peri-implant mucositis, and they found that MD in conjunction with enamel matrix derivative, air abrasive and 0.12% chlorhexidine mouthwash significantly improved BOP and PPD at 3 months following the treatment. In the group with enamel matrix derivative, PPD reduced from 5.40 ± 1.79 mm to 4.66 ± 1.95 mm. More studies are required to prove the efficacy of enamel matrix derivative in longer-terms.

After comparing different adjunctive therapies, we found that the use of ERL or repeated minocycline microspheres as an adjunct to MD treatment for peri-implantitis is better than chlorhexidine gel[12, 28]. Adjunct use of photodynamic therapy was as effective as one unit-dosage of minocycline microspheres or diode laser after 6 months of follow-up[15, 21, 22]. The efficacy of probiotics as an adjunct to the MD treatment was better than that of systemic antibiotics in reducing PPD and mBI. Further studies are needed to compare the effectiveness of different adjunctive therapies.

Conclusion

In summary, our study compared several therapies as adjuncts to the non-surgical MD treatment of peri-implantitis lesions. Our results showed that ERL, repeated minocycline microspheres, photodynamic therapy, modifying the prosthesis had significant effects in the short term (3 months), while air abrasive, chlorhexidine gel, probiotics, and system antibiotics had limited effects. ERL and photodynamic therapy showed no significant long-term effectiveness. These results should be interpreted with caution because limited studies included. At present, we do not know which non-surgical intervention is superior to any other, and for the interventions having similar degrees of effectiveness we do not know which one has less side effects, is simpler and cheaper to use. It is necessary to conduct well-designed RCTs with longer follow-ups to assess the accurate effectiveness of therapies.

List Of Abbreviations

RCTs: Randomized controlled trials

MD: Mechanical debridement

CAL: Clinical attachment level

PPD: Pocket probing depth

BOP: Bleeding of probing

PI: Plaque index

ERL: Er:YAG laser

Declarations

Ethics approval and consent to participate

All analyses were based on previous published studies, thus no ethical approval and patient consent are required.

Consent for publication

Not applicable

Availability of data and materials

All data are fully available without restriction.

Competing interests

The authors declare that they have no competing interests

Funding

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Authors' contributions

Yuhan Xiao and Haiyang Yu had made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. Yichun Qin had been involved in drafting the manuscript or revising it critically for important intellectual content. Haiyang Yu gave final approval of the version to be published. Haiyang Yu agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Figures

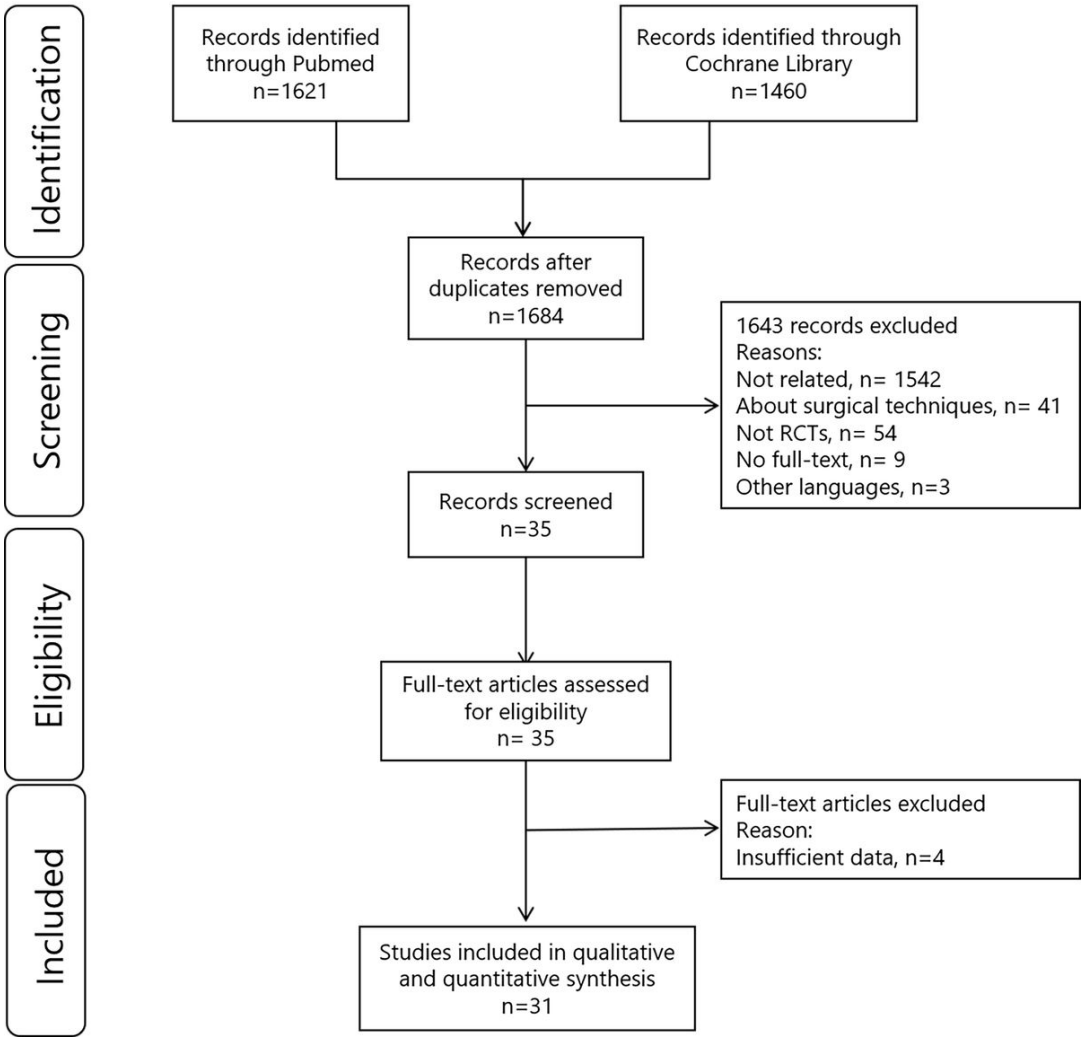

Figure 1

Flow chart of manuscripts screened throughout the review process.

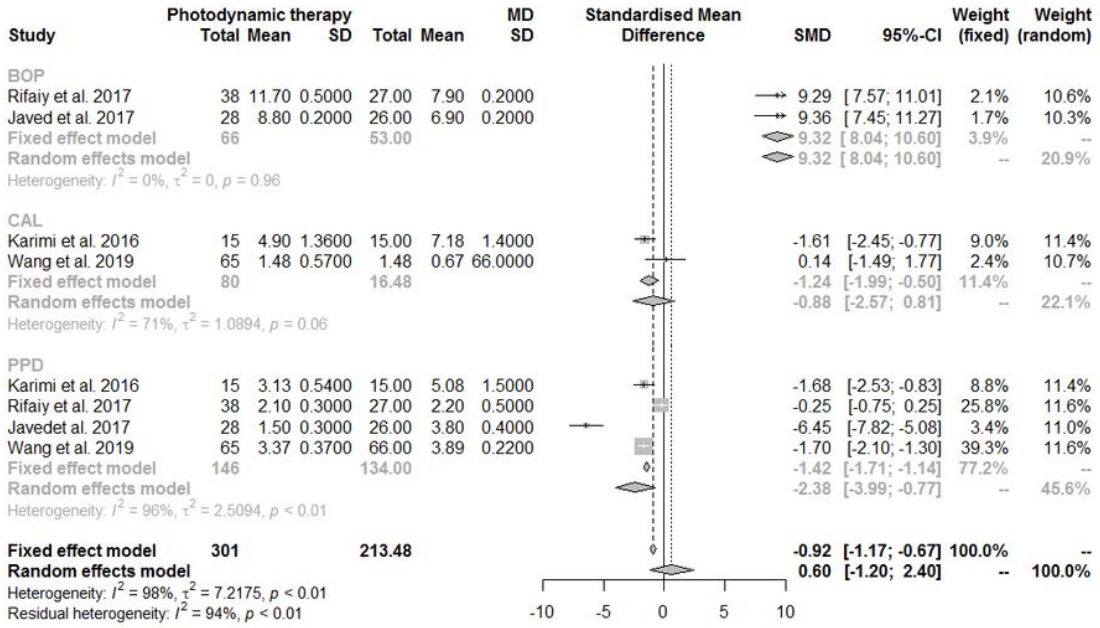

Figure 2

Meta-analysis compares the clinical outcomes of group MD with photodynamic treatment and group MD alone after 3 months follow-up.

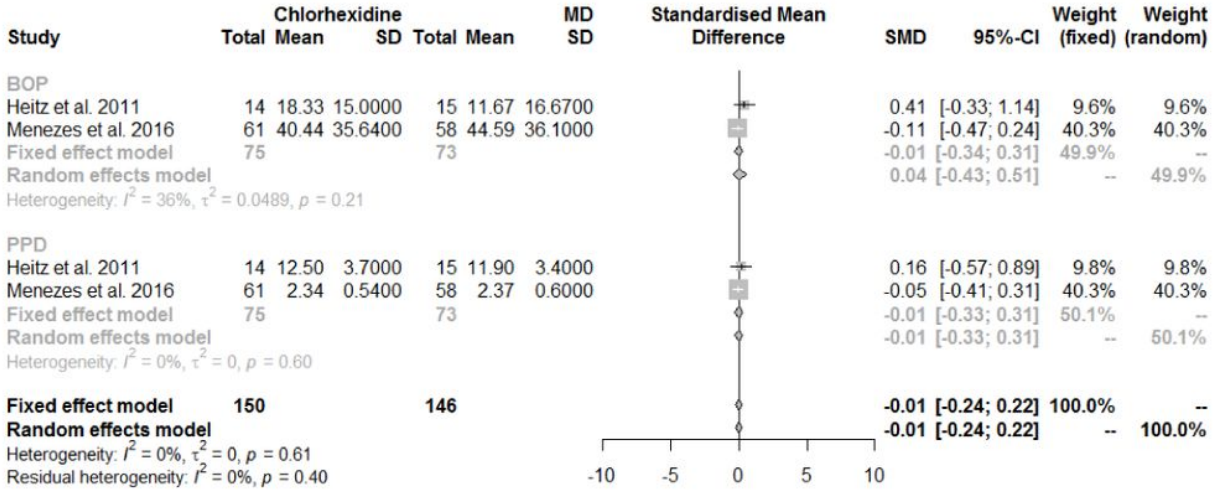

Figure 3

Meta-analysis compares the clinical outcomes of group MD with chlorhexidine treatment and group MD alone after 3 months follow-up.

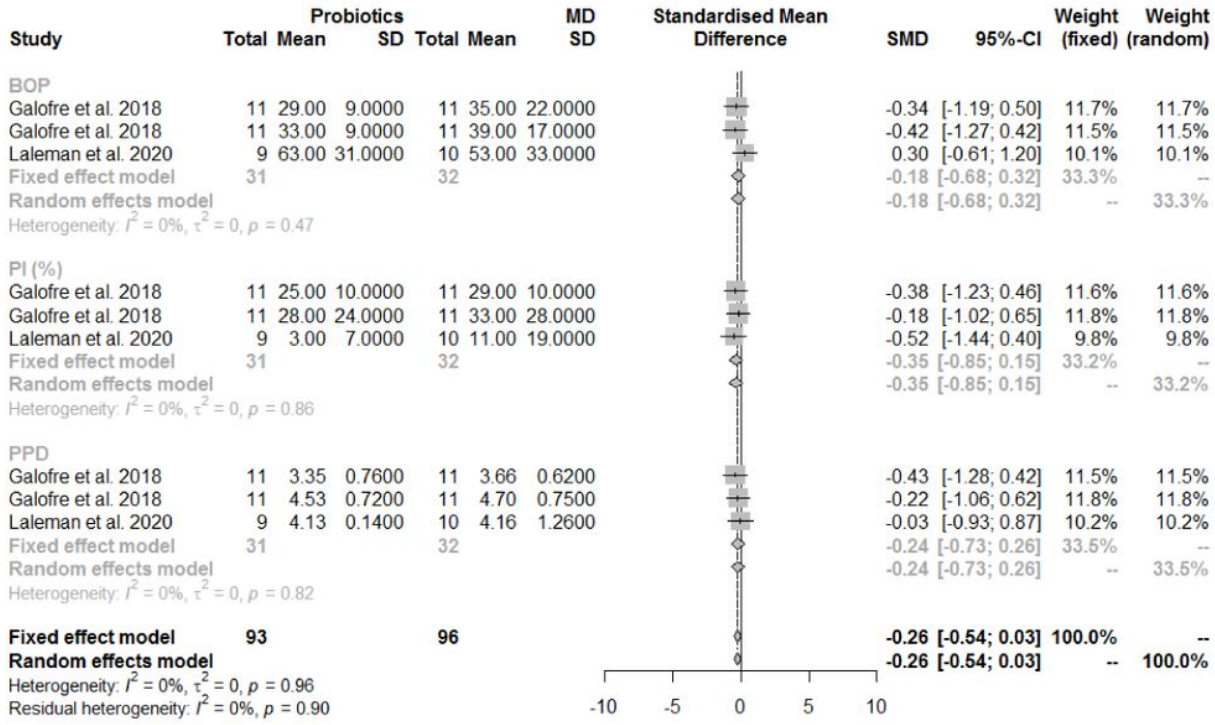

Figure 4

Meta-analysis compares the clinical outcomes of group MD with probiotics treatment and group MD alone after 3 months follow-up.

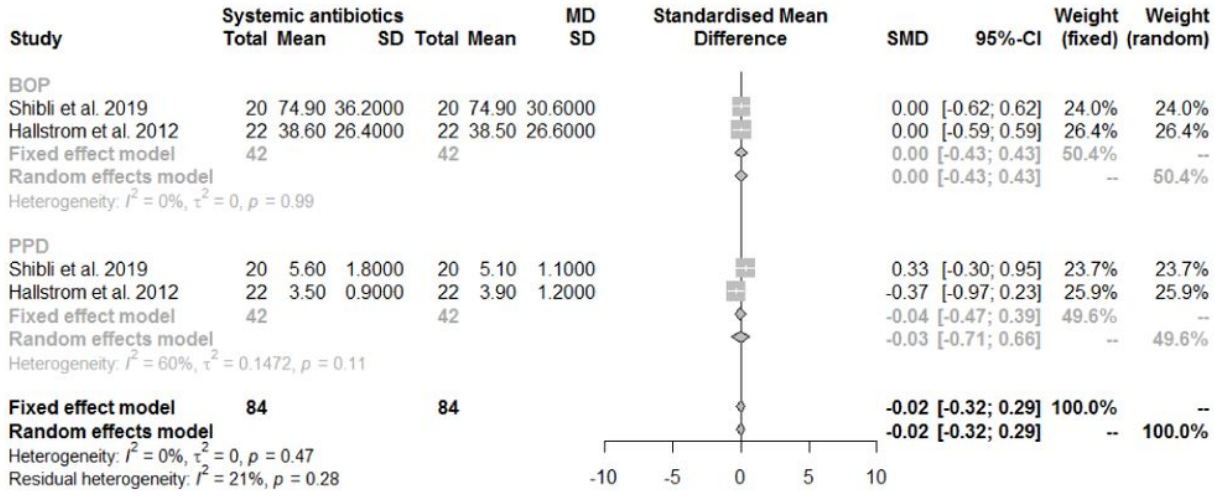

Figure 5

Meta-analysis compares the clinical outcomes of group MD with systemic antibiotics treatment and group MD alone after 3 months follow-up.

Supplementary Files

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